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(54) **Wave power generating apparatus of air-circulating type**

(57) Apparatus for generating electrical power from waves comprises a plurality of air pumping chambers (31 to 33) open to the waves, and air lines 37, 41 connected in parallel the chambers (31 to 33) by positive pressure check valves (34 to 36) and negative pressure check valves (38 to 40). A casing 44 is connected between the air passages (37, 41) and houses a turbine (42) and generator (43). The turbine being rotated by air flowing from the first air passage (37) to the second air passage (42). In one embodiment (not shown) the check valves are of the liquid seal type and an accumulator may be disposed in air passage 37.

F I G. 3

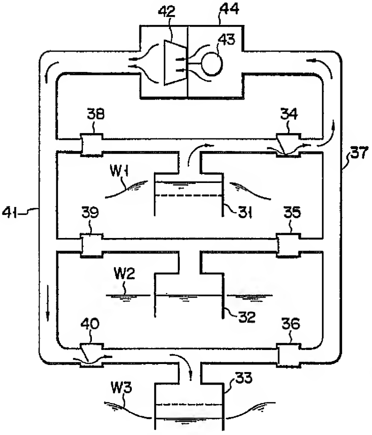

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FIG. 1

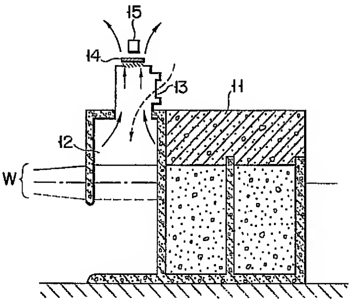


FIG. 2

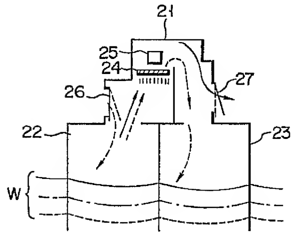
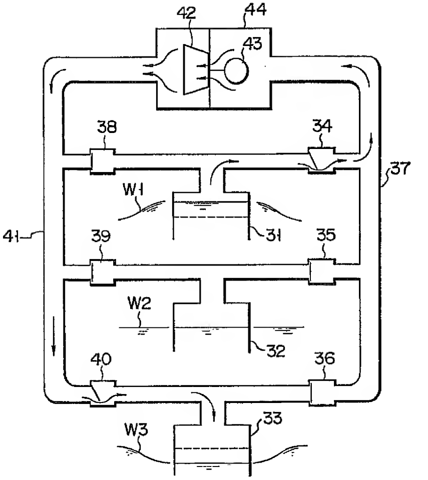


FIG. 3



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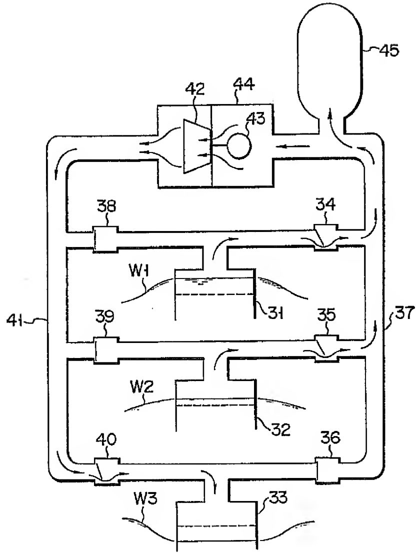

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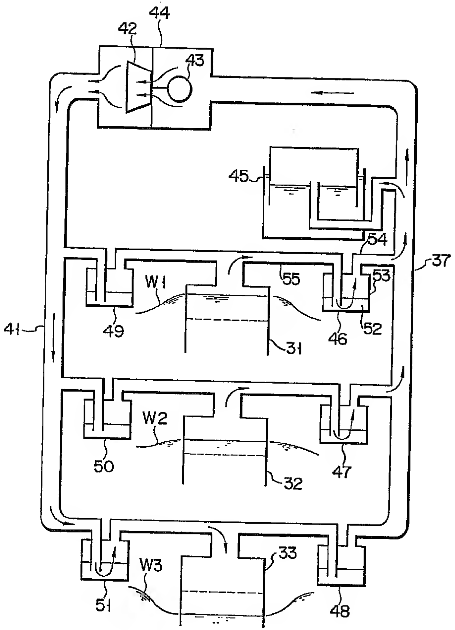

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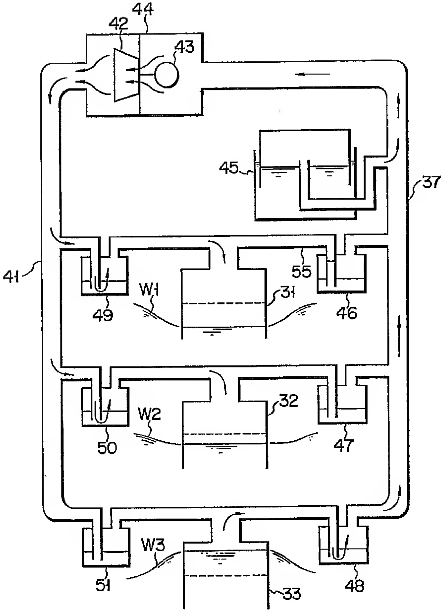

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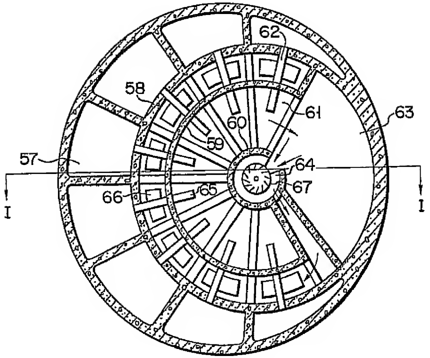
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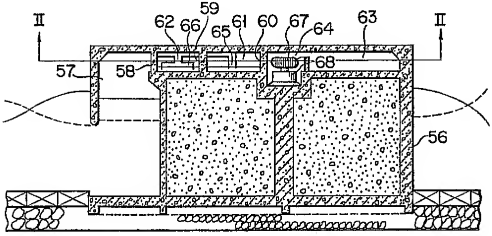
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SPECIFICATION

Wave power generating apparatus of air-circulating type

The present invention relates to an apparatus for generating electrical power by harnessing the energy of waves on the surface of water. Particularly, it relates to an improved air-circulating type apparatus having a plurality of air chambers in which the air pressures are changed by the waves, a valve mechanism which provides a stream of air from streams of air flowing in various directions, and a turbine which is driven by this air stream.

Various apparatuses are known which convert the energy of waves on the water surface into electrical power. They must fulfill three requirements. First, they should output constant electrical power in spite of the irregular motion of waves. Secondly, they should be protected from damage due to excessively high waves. Thirdly, the energy loss due to their valve mechanism should be minimized.

Figs. 1 and 2 schematically show two known wave power generating apparatuses called "fixed caisson type" and "buoy type".

The apparatus of Fig. 1 comprises a caisson 11 with an air chamber 12. Chamber 12 has open upper and lower ends with its lower end portion set below the sea surface and a valve 13 provided at its upper end portion of chamber 12. This valve allows air to flow into chamber 12 from the outside, not vice versa. An air turbine 14 is set at the upper end of chamber 12, and a generator 15 is provided above turbine 14, with its rotor shaft coupled to the shaft of turbine 14.

As the water level W falls to the level indicated by the broken line in Fig. 1, air flows from the outside into chamber 12 through valve 13. Conversely, as the level W rises to the level indicated by the solid line, air flows from chamber 12 through turbine 14. Turbine 14 therefore rotates to drive generator 15. That is, the apparatus of Fig. 1 generates electrical power as the water surface W moves up and down in eir chamber 12.

The apparatus of Fig. 2 comprises a moored buoy 21 floating in the sea. Buoy 21 has two air chambers 22 and 23. Each of these chambers is open at its upper and lower ends. The lower portions of both chambers are located below the sea surface. An air turbine 24 and a generator 25 are provided between the upper ends of the chambers 22 and 23. Two valves 26 and 27 are provided at the upper portions of chambers 22 and 23. Valve 26 allows air to flow into chamber 22 from the outside, and velve 27 allows air to flow from chamber 23 to the outside.

As the water level W falls to the level indicated by the broken line in Fig. 2, air flows in the direction of the broken-line arrows. As the water surface W rises to the level indicated by the solid line, air flows in the directions of the solid-line arrows. In either case, air turbine 24 rotates to drive generator 25, and the generator 25 generates electrical power as the water level W moves up and down in air chambers 22 and 23.

The conventional apparatuses have the following drawbacks. First, since the turbine is rotated by the stream of air created by the changes in pressure within the air chamber or chambers, the output power of the generator varies greatly, beceuse of the irregular motion of the waves. Secondly, the generator must have a large capacity and the turbine must be comparatively large so that a large electrical power mey be generated when the highest possible wave comes. Thirdly, since both the generator and the turbine must be large, the cost of the apparatus as a whole is inevitably high. Fourthly, since nothing is interposed between the turbine and generator, on one side, and the water surface W on the other, sea water may flow into the turbine and/or the generator when the waves are extremely high.

Accordingly, the object of this invention is to provide a wave power generating apparatus of an air-circulating type which can output constant electrical power, which need not be provided with a large turbine and a large generator or many turbines and many generators, but which can generate power with e high efficiency.

Another object of the invention is to provide a wave power generator apparatus of an air-circulating type in which a valve mechanism loses very little energy and which can continuously operate for a long time.

According to one aspect of the present invention, there is provided a wave power generating apparatus of an air-circulating type comprising: a plurality of air chambers in which the air pressures are changed by waves; a plurality of positive pressure check valves provided in these air chambers to open when the air pressure in the chambers is higher than the outside pressure; a plurality of negative pressure check valves provided in the air chambers to open when the air pressure in the chambers is lower than the outside pressure; a first air pessage for guiding air from the positive pressure check valves; a second air passage for guiding air from the negative pressure check valves; a turbine shielded from the atmosphere and connected between the first and second air passages to be driven by the streams of air in the first and second passages; and a generator shielded from the atmosphere and coupled to the turbine.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Figures 1 and 2 are side views of the

conventional wave power generating apparatuses;

Figure 3 schematically shows wave power generating apparatus according to the invention;

Figure 4 schematically illustrates a modification of the apparatus shown in Fig. 3;

Figures 5 and 6 schematically show other embodiments of the invention; and

Figure 7 is a plan sectional view of still another embodiment of the invention, taken along line II–II in Fig. 8; and

Figure 8 is a cross sectional view of the embodiment shown in Fig. 7, taken along line I–I in Fig. 7.

A few embodiments of the invention will now be described with reference to the accompanying drawings.

Fig. 3 schematically shows a first embodiment, i.e., a wave power generating apparatus. This apparatus comprises three air chambers 31, 32 and 33. Each of these chambers has an open upper end and an open lower end set below the sea surface. The upper ends of chambers 31, 32 and 33 are connected by positive pressure check valves 34, 35 and 36 to a first air passage 37. They are also connected by negative pressure check valves 38, 39 and 40 to a second air passage 41.

A casing 44 is connected between first air passage 37 and second air passage 41. Housed in this chamber are an air turbine 42 and a generator 43. Turbine 42 and generator 43 are shielded by casing 44 from the atmosphere.

The operation of the apparatus shown in Fig. 3 will be described. Suppose the water level W1 in chamber 31 rises above the reference level indicated by the broken line, and the water level W3 in chamber 33 falls below the reference level also indicated by the broken line. In this case, the air pressure in chamber 31 rises, thus opening check valve 34, and the air pressure in chamber 33 falls, thus opening check valve 40. As a result, air flows from first air passage 37 to second air passage 41. Turbine 42 is driven by the stream of air. The generator 43 is driven by turbine 42 to generate electrical power. When water levels W1, W2 and W3 in chambers 31, 32 and 33 change in the manner different from that illustrated in Fig. 3, the air also flows from air passage 37 to second air passage 41.

Therefore, air turbine 42 continuously rotates in the same direction. It functions as a damper for the stream of air, so that the output power of generator 43 is regulated. Air chambers 31, 32 and 33 are arranged in the direction of the wave motion, so that the water surface in one chamber rises when the water level in another is falling. Hence, air turbine 42 can be driven with a high efficiency even if the waves are rather low.

Since turbine 42 and generator 43 are shielded from the atmosphere by casing 44, no sea water flows into them even if the waves are extremely high. Since the energy of the air created in any air chamber is only supplied to one place, i.e., casing 44, only one turbine and only one generator suffice. Moreover, since the sum of the air pressures in the air chambers is constant and is never extremely high, neither turbine 42 nor generator 43 needs to be large. The apparatus is comparatively inexpensive and its maintenance cost is low.

Fig. 4 shows a modification of the first embodiment shown in Fig. 3. This apparatus is different from that of Fig. 3 only in that an air tank 45 is connected to a first air passage 37. Tank 45 compensates for the total volume of passages 37 and 41 which is smaller than the total volume of air chambers 31, 32 and 33. When too large an amount of air flows from any air chamber to first air passage 37, its excessive portion flows into tank 45 so that a proper amount of air is supplied to a turbine 42. On the other hand, when too small an amount of air flows from any air chamber to first air passage 37, the air flows from tank 45 to turbine 42 so that a proper amount of air is supplied to turbine 42. Since the same amount of air is supplied to turbine 42, the output power of a generator 43 does not vary.

Figs. 5 and 6 show a second embodiment of the invention. This apparatus is different from the first embodiment (Fig. 3) in that water check valves 46 to 51 are used in place of check valves 34 to 40 and that an air tank 45 is coupled to a first air passage 37. Valves 46 to 51 are identical in structure, and only valve 46 will be described here with reference to Fig. 5.

Water check valve 46 comprises an envelope 53 containing water 52, a pipe 54 connected at one end to the top wall of envelope 53 and at the other end to first air passage 37, and a pipe 55 passing through the top wall of envelope 53 with its lower end in the water 52 and its other end coupled to air chamber 31. No gap is made between the top wall of envelope 53 and the periphery of pipe 55.

When the water level W1 in air chamber 31 rises above the reference level as shown in Fig. 5, the air pressure in chamber 31 rises. The cross section of pipe 55 is smaller than the difference between it and the cross section of envelope 53. Therefore, the air in chamber 31 flows into first air passage 37. Conversely, when the water surface W1 falls below the reference level as shown in Fig. 6, the air pressure in chamber 31 falls. In this case, water 52 rises in pipe 55, thus preventing the air from flowing back into chamber 31 from first air passage 37. Water check valves 47 and 48 work in the same way as valve 46.

Unlike water check valves 46 to 48, valves 49 to 51 supply air from a second air passage 41 to air chambers 31, 32 and 33 when the air pressures in these chambers fall below the reference value.

Water check valves 46 to 51 more quickly and reliably respond to the changes of the air pressures in chambers 31 to 33 than mechanical, positive pressure check valves 34 to 36 and mechanical, negative pressure check valves 38 to 40 (Fig. 3). The energy loss in the apparatus of Figs. 5 and 6 is therefore less than that in the first embodiment. Moreover, since each water check valve has no movable members, it can last longer than mechanical valves 34 to 36 and 38 to 40 which have movable members.

Air tank 45 of the second embodiment (Figs. 5 and 6) contains water and is so designed that its volume can change as illustrated in Figs. 5 and 6. It can more efficiently control the energy of air applied to a turbine 42 than the air tank used in the apparatus of Fig. 4 whose volume cannot change. The output power of the second embodiment is therefore more constant than that of the apparatus shown in Fig. 4.

Figs. 7 and 8 show a third embodiment of this invention which is a wave power generating apparatus of the fixed caisson type with a plurality of air chambers arranged in an arc. This apparatus comprises a circular base 56. Base 56 has a cylindrical wall, walls extending in radial directions and concentric arcuate walls 58, 59 and 60. These walls define air chambers 57, an arcuate first air passage 61, an arcuate second air passage 62, an air tank 63 and a casing 64. An air turbine 67 and a generator 68 are housed within casing 64. The apparatus further comprises a plurality of positive pressure, water check valves 65 which connect air chambers 57 to first air passage 61. Negative pressure, water check valves 66 connect chambers 57 to second air passage 62.

When the air pressure in any air chamber rises, air flows from the chamber into first air passage 61 through valve 65. When it falls, the air flows from second air passage 62 into the air chamber. Therefore, the air flows in the directions of arrows shown in Fig. 7. That is, it flows into second air passage 62 through first air passage 61, air tank 63 and casing 64. This stream of air drives turbine 67, whereby generator 68 coupled to turbine 67 generates electrical power.

The sizes and positions of chambers 57, turbine 67, passages 61 and 62 and valves 65 and 66 should be determined in accordance with the waves to be utilized. For example, when coastal waves are used, water check valves 65 and 66 must be immersed in the water to the depth of 1 to 10 cm, and the ratio of the cross section of the pipe of each valve to the difference between it and the cross section of the envelope thereof is 3 to 10.

The present invention can be applied to wave power generating apparatuses of both the fixed caisson type and the buoy type. The apparatuses according to the invention can be incorporated into the coastal facilities such as waterbreaks.

CLAIMS

1. A wave power generating apparatus of an air-circulating type comprising:

a plurality of air chambers in which the air pressures are changed by waves;

a plurality of positive pressure check valves provided for these air chambers to open when the air pressures in the chambers are higher than the outside pressure;

a plurality of negative pressure check valves provided in the air chambers to open when the air pressure in the chambers is lower than the outside pressure;

a first air passage for guiding air from the positive pressure check valves;

a second air passage for guiding air from the negative pressure check valves;

a turbine shielded from the atmosphere and connected between the first and second air passages to be driven by the streams of air in the first and second passages; and

a generator shielded from the atmosphere and coupled to the turbine.

2. A wave power generating apparatus according to claim 1, further comprising an air tank coupled to said first air passage.

3. A wave power generating apparatus according to claim 2, wherein said air tank contains water and is so designed that its volume is changed as the internal air pressure changes.

4. A wave power generating apparatus according to any one of the preceding claims, wherein said positive pressure check valves and said negative pressure check valves are water valves each comprising an envelope containing water, and opening and closing as the water level changes due to changes in the internal air pressure.

5. A wave power generating apparatus of air-circulating type, substantially as hereinbefore described with reference to Figs. 3 to 8 of the accompanying drawings.

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